

## **7<sup>th</sup> National Clean Cities Conference**

### ***Developing International GHG Reduction Projects Using AFV Technologies***

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#### **Case Study: Electric Vehicle Taxis**

##### ***1 Introduction***

The following case study is based on a hypothetical project that involves the deployment of 125 electric battery charged taxis to replace 125 gasoline-fueled taxis.

This case study focuses on the process of developing an emissions baseline and estimating net greenhouse gas (GHG) emission benefits of an individual project. Other criteria for project development under a market-based GHG reduction scheme are discussed in less detail – mainly because the proposals and rules for controlling GHGs are still evolving and are likely to change as the U.S. and other nations decide on the specific procedures for limiting GHG emissions. Although the guidance for developing national and international GHG reduction projects are still being developed, this case study should still be useful for providing overall guidance on how to estimate and document the potential emission benefits of an electric vehicle project. This analysis does not discuss methodologies for developing standardized or multi-project baselines for the transportation sector.

In the following subsections we will provide a brief summary of the project case study, outline the general criteria for developing a GHG reduction project under current market-based proposals for GHG control, develop the project based on these criteria, and estimate the emissions baseline and net project benefits.

##### ***2 Project Background***

This case study is based on a hypothetical project in a country called the Clean Cities Republic.<sup>1</sup> Although the Clean Cities Republic is a developing country, it does not

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<sup>1</sup> The hypothetical country example of the Republic of Clean Cities was first introduced at the 6<sup>th</sup> National Clean Cities Conference for illustrating a similar case study on estimating the GHG benefits of a natural gas vehicle project. Julie Doherty and Jette Findsen, “Case Study: CNG Taxis, The Republic of Clean

represent any country or region in particular. It should be emphasized that the numbers used for this case study are invented as well. The data provided for estimating the emissions baseline have been developed for illustrating how to quantify potential emission benefits, not as an indicator of the specific emissions potential of an electric vehicle project. Electric vehicle project developers should obtain their own GHG emission data for both the conventional vehicles to be replaced and the new alternative fuel vehicles to be introduced.

The Republic of Clean Cities is a country with a population of 45 million people. Gross domestic product (GDP) is U.S.\$190 million per year, with an annual growth rate of 5 to 6 percent over the last 10 years. As a result of this economic expansion, the country is experiencing an energy demand growth of 7 percent per year, with the transportation sector representing the fastest growing energy sector. Currently, transportation activities account for 32 percent of energy related CO<sub>2</sub> emissions, however this share is expected to grow significantly over the next few decades as the transportation sector continues to expand.

The project will be located in the capital of the Republic of Clean Cities, which is a city of 8 million people with a population growth of 5 percent per year. On average there are 7 people per motor vehicle compared to 1.3 per vehicle in the U.S. The total number of vehicles on the road is growing by 7 percent annually. The capital is experiencing serious local environmental pollution problems and is among the 20 most polluted cities in the world. The concentration of total suspended particulates (TSP) in the air is 8 times higher than the proposed World Health Organization (WHO) standards. The majority of the capital's pollution problems are caused by transportation emissions. To alleviate some of these environmental problems, the government has introduced tax incentives for switching to AFVs. A couple of years ago, a new law was passed mandating that all new cars should drive on unleaded gasoline. Currently, 40 percent of all gasoline sold in the country is leaded. The local government has introduced a car use reduction plan to curb the rapid growth of new vehicles in the capital area. Finally, a new domestic regulation was put in place this year for reductions in tailpipe emissions of urban pollutants.

To date, no electric vehicles have been purchased in the capital and there are no domestic manufacturers or dealers supplying this type of vehicle.

### **3      *The Project Case Study***

As part of the project, 125 dedicated electric vehicles (sedans) will be purchased instead of 125 conventional gasoline taxis of a similar size. To develop a supporting infrastructure, vehicle accessible electrical outlets will be provided at the site where these taxis are parked, including at the homes of the taxi drivers. Moreover, an extensive training course will be provided for the fleet mechanics. The lifetime of the project is estimated conservatively at 12 years. Each taxi is expected to drive an average of 70,000 miles per year. The energy use of the electric vehicles is 1.46 kwh/mile and the mileage

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Cities,” Presentation for the NETL-sponsored training session, *Developing International Greenhouse Gas Emission Reduction Projects Using Clean Cities Technologies*, in San Diego, CA, May 10, 2000.

of the conventional gasoline vehicles that would have been purchased in the absence of the project is 26 miles per gallon of gasoline.

The project participants include the Capital City Transportation Department, a local taxi fleet operator, and a U.S.-based electric vehicle manufacturer. The electric vehicle project has been approved by the Republic of Clean Cities' National Climate Change Office, which has been authorized by the Ministries of Foreign Affairs, Energy, and Environment to evaluate and certify internationally sponsored GHG reduction projects. The National Climate Change Office, administered by the Ministry of Environment, has provided written documentation of project approval.

The project reduces CO<sub>2</sub> emissions by reducing the need for oil recovery, gasoline refining, and fuel transportation, which produces more CO<sub>2</sub> emissions than recharging the electric batteries. The carbon intensity of electricity generated in the capital region is relatively low, as more than 35 percent of the generating capacity relies on hydropower. A comparison of N<sub>2</sub>O and CH<sub>4</sub> emissions will not be included in the emissions baseline because none of these contribute significantly to projected emissions.<sup>2</sup>

#### **4      *Project Additionality***

As mentioned earlier, the criteria for evaluating market based GHG reduction projects have still not been agreed on. Yet, the requirement that a project activity must be implemented *in addition to* what would have happened without the GHG control scheme is likely to remain part of any future market based approach. This requirement is important as it ensures that projects receiving credit actually do lead to *new* GHG reduction initiatives, and that other business-as-usual projects, already scheduled for implementation, do not receive any credit. Because the rules for determining additionality are still evolving, the discussion of additionality for this case study can only be preliminary in scope and is included mostly to illustrate the types of information that could be included in such an analysis.

Determining the additionality of the electric vehicle (EV) project is pretty straightforward. As mentioned earlier, there are no electric vehicles in the capital and the technology is not yet commercially available on the domestic market. One major impediment for the introduction of EVs is the considerable higher cost of the vehicles and the lack of knowledge about the technology. Although tax incentives are provided for owners of alternative fuel vehicles (AFVs) there are no laws or regulations requiring

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<sup>2</sup> Among the different proposed and existing programs for evaluating and crediting GHG reduction projects, no guidance has been provided detailing whether all project related GHG emissions should be included in the baseline analysis, or whether only the most significant gases and sources should be included, and if so when. The most useful guidance on this issue can be gleaned from the U.S. Initiative on Joint Implementation (USIJI). This program was introduced during the Activities Implemented Jointly (AIJ) Pilot Phase of the United Nations Framework Convention on Climate Change (UNFCCC) and applies some of the most stringent application criteria of all the national AIJ/JI offices. According to the criteria of USIJI, the emission baseline should include *major* emission sources and GHGs from the project. "Resource Document on Project & Proposal Development under the U.S. Initiative on Joint Implementation (USIJI)," U.S. Initiative on Joint Implementation, Version 1, June 1997.

public or private vehicle fleet owners to purchase alternative fueled vehicles, such as EVs. It is therefore unlikely that electric vehicles will be introduced in the country in the near future. The EV project is clearly additional and would likely qualify for credit under any market based GHG reduction program.

## **5      *Estimating the Emissions Baseline***

Since the introduction of the concept of cooperatively implemented GHG reduction projects and other market based procedures for limiting GHG emissions, little experience has been gained regarding the development and evaluation of transportation-related GHG reduction projects. Only one transportation project has been approved under the UNFCCC's Activities Implemented Jointly (AIJ) Pilot Phase, which was initiated to test the concept of joint implementation (JI) whereby investors in one country can invest in GHG mitigation projects in any other country. One project, however, does not provide enough precedence to be used for the development of standardized methodologies for analyzing transportation projects. Instead, potential developers of transportation projects must use the general experience gained from the AIJ Pilot Phase and the preliminary rules proposed under other market based programs for controlling GHGs.

A useful place to look for guidance on project development is the U.S. Initiative on Joint Implementation (USIJI). This program was introduced during the AIJ Pilot Phase and applies some of the most stringent application criteria of all the national AIJ/JI offices.<sup>3</sup> According to the criteria of USIJI, the emission baseline should include *major* emission sources and GHGs from the project.<sup>4</sup> For this type of project proposal it may be sufficient to include information about CO<sub>2</sub> emissions only, instead of covering all greenhouse gases. However, it is possible that a future market-based regime would require a more stringent analysis of potential emission reductions. Clearly, the analysis should include a comparison of upstream emissions because the project emissions are dependent on the fuel mix used for generating the electricity used in the batteries. In other cases, such as a previous case study developed on compressed natural gas vehicles<sup>5</sup>

Because of the many unanswered questions related to the requirements of establishing an emissions baseline, this study will provide three sample baseline scenarios to illustrate how different project characteristics may influence the baseline estimate. The three baselines include:

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<sup>3</sup> The status of USIJI is currently under review pending a decision of the White House Administration regarding how to proceed with the international negotiations on climate change. No new projects can be submitted for evaluation under USIJI until the Administration has made a decision on the future of the program.

<sup>4</sup> "Resource Document on Project & Proposal Development under the U.S. Initiative on Joint Implementation (USIJI)," U.S. Initiative on Joint Implementation, Version 1, June 1997. Emphasis added by authors.

<sup>5</sup> Billups, et. al. "Greenhouse Gas Emission Reductions and Natural Gas Vehicles: A Resourceguide on Technology Options and Project Development" National Energy Technology Laboratory (NETL), March 2001.

1. A static baseline assuming that the 125 new electric vehicles are purchased instead of 125 new conventional gasoline powered vehicles. These vehicles are purchased to meet growing demand for taxi services.
2. A dynamic baseline assuming that the 125 new electric vehicles will replace 125 aging conventional gasoline vehicles with an estimated average life time of eight years.
3. A static baseline assuming that the 125 new electric vehicles are purchased instead of 125 new conventional gasoline powered vehicles. This analysis includes a full fuel cycle analysis similar to that provided in the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model.

The purpose of presenting these different baseline scenarios is two-fold. One reason is to advance the discussion on some of the issues that must be resolved in order to establish clear guidelines for the documentation and approval of transportation-related projects. Another reason is to provide potential project developers with an idea of the issues that must be considered during the development of an emissions baseline for a transportation project. Project developers can then choose between or combine the different levels of baseline scenarios depending on the purpose and requirements of the program to which the project participants will be applying for credit. Factors which may determine the choice of baseline scenarios, include:

1. The transportation technology used for the project
2. Availability of full fuel cycle and tailpipe emissions data
3. Individual GHG program requirements
4. The risk tolerance and level of accuracy desired by project developers and investors
5. The acceptable level of transaction costs

In the following subsections, the three baseline scenarios will be outlined. Each version of the baseline scenarios involves three quantification steps. These include a calculation of; (1) the project reference case, (2) project-related emissions, and (3) net emission benefits of the project.

The first quantification step entails an estimation of what emissions would have been without the implementation of the project. This step is also known as the emission baseline or the project reference case and should include data for the entire life of the project. Because the potential project emission benefits are derived by comparing project emissions to the reference case, accuracy in the development of the reference case is very important. However, estimating future emissions is a difficult process. It is almost impossible to factor in everything that may or may not happen 10 to 20 years down the road. Moreover, many different results can be achieved depending on which assumptions are used to derive the future emissions scenario.<sup>6</sup> GHG reduction programs and project developers planning to receive credit for their projects under a future market-based GHG reduction program have to be careful to develop baseline criteria that would be stringent

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<sup>6</sup> The UNFCCC text establishing the Activities Implemented Jointly (AIJ) Pilot Phase provided little guidance on how specifically to estimate future emissions. Hence, the various national JI programs evaluating projects under the AIJ Pilot Phase applied different criteria for estimating the reference case.

enough to be accepted under any program. Given the differences between the various initiatives to credit GHG reduction initiatives, developers should consult the preliminary guidelines of each of the proposed programs before developing a project, and be careful to detail all assumptions and emission sources when quantifying the potential emission benefits. The examples provided in the following case study are less comprehensive and should only be used as an indicator of the types of data and quantification procedures that could be required from the different GHG reduction programs.

The third quantification step involves estimation of emissions from the project itself. The data provided should include an estimation of all relevant project emissions throughout the life of the project. During this process, project developers should be careful to define the boundary of the project and detail all the assumptions and emission sources included in the estimate.

The fourth and final quantification step is very simple. It entails the calculation of the net emission benefits of the project. To derive the net benefits, the project developer must subtract the project emissions from the emissions estimated for the reference case. The difference will represent the net emissions benefits of the project.

#### 5.1 Emission Baselines: Version 1

The first scenario will be based on a static emissions baseline. This means that the emissions are assumed to remain constant throughout the life of the project. This scenario does not take into consideration changes to vehicle emissions and equipment over time.

In version 1, the method used to calculate emission reductions is based on a comparison of fuel usage and the emission factors of the fuels used.

##### *Step 1: The Reference Case*

The reference case represents what would have happened if the GHG reduction project were not implemented. In this case, it is assumed that, without the GHG reduction project, 125 new conventionally fueled gasoline vehicles would have been purchased to satisfy the growing demand for taxi services. Because version 1 of the case study assumes that emissions of the project are static, the GHG emissions of one taxi over the next 12 years will remain the same.

In this version of the case study, the formula for calculating emissions of the gasoline vehicles is:

$$\text{Emissions} = (\text{miles/miles per gallon}) \times (\text{emission factor of gasoline}) \times (\text{number of vehicles}) \times (\text{number of project years})$$

The emission factor for gasoline is assumed to be 19.564 lbs CO<sub>2</sub>/gallon.<sup>7</sup> Hence emissions without the project would have been:

$$\text{Emissions} = (70,000/26) \times (19.564 \text{ lbs CO}_2/\text{gallon}) \times (125) \times (12) = \underline{35,848 \text{ metric tons CO}_2}$$

### *Step 2: The Project Case*

The project case represents emissions of the project itself. In this instance, the project case refers to the emissions of the 125 electric vehicle taxis over the 12 year life of the project.

In this version of the case study, the formula for calculating emissions of the electric vehicles is:

$$\text{Emissions} = (\text{miles/kWh per mile}) \times (\text{emission factor of electricity generation}) \times (\text{number of vehicles}) \times (\text{number of project years})$$

The emission factor for electricity generation in the capital area is assumed to be 0.178 metric tons CO<sub>2</sub>/MWh. Hence emissions with the project would be:

$$\text{Emissions} = (70,000/1.46 \text{ kWh per mile}) \times (0.000178 \text{ metric tons CO}_2/\text{kWh}) \times (125) \times (12) = \underline{12,801 \text{ metric tons CO}_2}$$

### *Step 3: Deriving Net Project Benefits*

The net project emission benefits are derived by subtracting the project case from the reference case. As illustrated below, the net project benefits of version 1 of the case study are 23,046 metric tons of CO<sub>2</sub>.

Reference case	-	project case	=	Net project benefits
35,848	-	12,802	=	<u>23,046</u> metric tons of CO <sub>2</sub>

## 5.2 Emission Baselines: Version 2

The second scenario for the electric vehicle project relies on a dynamic emissions baseline. A dynamic baseline takes into account the changes that may happen to emissions and equipment as the vehicles age over time. In this version of the case study, we assume that the 125 new electric vehicles will replace an equal number of aging

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<sup>7</sup> U.S. Department of Energy, Energy Information Administration (EIA), Instructions for the Voluntary Reporting of Greenhouse Gases Program.

gasoline vehicles. However, as the old vehicles only have an estimated average lifetime of 8 years left, we have to assume that a similar number of new gasoline vehicles would be purchased after 8 years to replace the old vehicles as they are taken out of service. Therefore, in this version of the case study we assume that the mileage of the old gasoline vehicles is considerable lower than the mileage of the new gasoline vehicles that are projected to be purchased 8 years into the future.

### *Step 1: The Reference Case*

The reference case represents what would have happened if the GHG reduction project were not implemented. As this is a dynamic baseline that takes into account the fact that the old gasoline vehicles are expected to be taken out of service after an average of 8 years – and be replaced with new gasoline vehicles – the reference case will have to be calculated in two steps. First, the emissions of the old vehicles during the first 8 years of the project will be calculated, then the emissions of the new vehicles used during the last 4 years of the project lifetime will be estimated. The two numbers will then be added together and will represent the emissions of the reference case. It is assumed that the mileage of the old gasoline vehicles is 21 gallons per mile while the mileage of the new vehicles will be 28 gallons per mile.

The formula for calculating emission reductions will be the same as in version 1 of the case study:

$$\text{Emissions} = (\text{miles/miles per gallon}) \times (\text{emission factor of gasoline}) \times (\text{number of vehicles}) \times (\text{number of project years})$$

The emission factor for gasoline is assumed to be 19.564 lbs CO<sub>2</sub>/gallon.<sup>8</sup> Hence emissions without the project would have been:

$$\text{Emissions (old vehicles)} = (70,000/21) \times (19.564 \text{ lbs CO}_2/\text{gallon}) \times (125) \times (8) = 29,589 \text{ metric tons CO}_2$$

$$\text{Emissions (new vehicles)} = (70,000/28) \times (19.564 \text{ lbs CO}_2/\text{gallon}) \times (125) \times (4) = 11,096 \text{ metric tons CO}_2$$

$$\text{Emissions of all gasoline vehicles} = 29,589 + 11,096 = \underline{40,685 \text{ metric tons CO}_2}$$

### *Step 2: The Project Case*

The project case represents emissions of the project itself. In this situation, the project emissions will remain the same as version 1 of the case study. Hence, project emissions are 12,801 metric tons CO<sub>2</sub>.

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<sup>8</sup> U.S. Department of Energy, Energy Information Administration (EIA), Instructions for the Voluntary Reporting of Greenhouse Gases Program.

### *Step 3: Deriving Net Project Benefits*

The net project emission benefits are derived by subtracting the project case from the reference case. As illustrated below, the net project benefits of version 2 of the case study are 8,961 metric tons of CO<sub>2</sub> equivalent.

Reference case	-	project case	=	Net project benefits
40,685	-	12,801	=	<u>27,884</u> metric tons of CO <sub>2</sub>

### 5.3 Emission Baselines: Version 3

The third version of the emission baseline for the electric vehicle project relies on a static emission baseline, but uses a different model for quantifying the emissions benefits. In the previous two versions of the case study, emissions benefits were estimated by comparing fuel usage of the different vehicle types. However, this method does not account for the entire emissions scenario of the project. A more accurate analysis of emission benefits would analyze the entire project life cycle, including emissions from the production, transportation, processing, and combustion of the fuel used. However, this type of analysis is very complicated and would be costly to undertake for the individual project developer.

For projects in the United States, it would be possible to undertake this type of analysis by using the GREET model developed by Argonne National Laboratory.<sup>9</sup> As part of this model, emissions have been computed for a number of different vehicle types and models based on a detailed analysis of the energy production and usage of the entire transportation sector. Project developers can apply data regarding a specific vehicle model to the GREET model and calculate the potential GHG and other emission reductions from a project. However, this model only applies to the transportation sector in the U.S. No similar studies have been undertaken in other countries. In particular, developing countries lack the adequate data and resources to undertake such studies of life cycle emissions.

In the following version of the case study, we have applied hypothetical electric vehicle data to the GREET model to illustrate how emissions would be calculated using this model. Hence, this baseline is more detailed than the two previous versions; that is, emissions data is presented for three stages of the fuel cycle. These stages include feedstock (production, transportation, and storage of primary energy feedstock), fuel (production, transportation, storage and distribution of energy source), and vehicle operation (fuel combustion or other chemical conversion).

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<sup>9</sup> Michael Wang “Greenhouse Gases , Regulated Emissions, and Energy Use in Transportation (GREET)”. Argonne National Laboratory. [www.transportation.anl.gov/ttrdc/greet](http://www.transportation.anl.gov/ttrdc/greet)

### *Step 1: The Reference Case*

The reference case represents what would have happened if the GHG reduction project were not implemented. As in the first version of this case study, it is assumed that 125 conventional gasoline taxis would have been purchased instead of the electric vehicles. We assume that the annual emissions of one gasoline vehicle turn out as described in Table 1.

**Table 1: Version 3 of Case Study – Annual Emissions Without the Project**

	<b>Feedstock</b>	<b>Fuel</b>	<b><u>Grams/mile/year</u> Vehicle Operation</b>	<b>Total</b>
CO <sub>2</sub>	19	86	402	507

#### Emissions over 12 years:

507 g CO<sub>2</sub> /mile x 70,000 miles x 125 cars x 12 years = 53,249 metric tons of CO<sub>2</sub>

### *Step 2: The Project Case*

As in the previous versions of this case study, the project case refers to the emissions of the 125 electric vehicle taxis over the 12-year life of the project. It is assumed that emissions of the electric vehicles will remain constant over the life of the project. Hence, we use a static baseline. We assume that the annual emissions of one electric vehicle turn out as described in Table 2.

**Table 2: Version 3 of Case Study – Annual Emissions With EV Project**

	<b>Feedstock</b>	<b>Fuel</b>	<b><u>Grams/mile/year</u> Vehicle Operation</b>	<b>Total</b>
CO <sub>2</sub>	21	237	0	258

#### Emissions over 12 years:

258 g CO<sub>2</sub> /mile x 70,000 miles x 125 cars x 12 years = 27,097 metric tons of CO<sub>2</sub>

### *Step 3: Deriving Net Project Benefits*

The net project emission benefits are derived by subtracting the project case from the reference case. As illustrated below, the net project benefits of version 3 of the case study are 26,152 metric tons of CO<sub>2</sub>.

Reference case	-	project case	=	Net project benefits
53,249	-	27,097	=	<u>26,152</u> metric tons of CO <sub>2</sub>